ORIGINAL ARTICLE

Physiological response in professional female soccer players: Comparison between small-sided games and laboratory exercise testing

Tommy Apriantono . *Department of Sports Science, School of Pharmacy. Bandung Institute of Technology. Bandung, Indonesia.*
Wildan Bahrul U'Lum. *Department of Sports Science, School of Pharmacy. Bandung Institute of Technology. Bandung, Indonesia.*
Nia Sria Ramania. *Department of Sports Science, School of Pharmacy. Bandung Institute of Technology. Bandung, Indonesia.*
Bagus Winata. *Department of Sports Science, School of Pharmacy. Bandung Institute of Technology. Bandung, Indonesia.*

ABSTRACT

The aim of this study was to describe the physiological characteristics and energetic requirements of small-side games (SSG) in female players by means of ambulatory gas exchange measurements using a breath-by-breath (B × B) approach. Eight female professional soccer players participated in this study. This study was divided into two sessions: laboratory exercise testing and SSG field testing. Both tests were performed using simultaneous gas exchange measurements. The incremental ramp exercise test was performed using portable metabolic carts breath by breath (B×B) and a treadmill, to measure the maximum oxygen uptake (VO_{2max}) and maximum heart rate (HR_{max}) of each player. In the SSG field test, the metabolic carts (B×B), was used during SSG to measure oxygen uptake (VO_2), average heart rate (HR_{ave}), breath frequency (fB), minute ventilation (VE), energy expenditure (EE), and heart Rate and O_2 Pulse (VO_2/HR). Activity profiles were assessed by professional technical coaches (n = 2). A total of 152 passes were included in the four-a-side SSG analysis. Specifically, 85.53% of the total passes were categorized as successful passes and 14.47% were categorized as failed passes. VO_2 during SSG was 83.90% of the VO_{2max}, and HR_{ave} during SSG was 84.42% of the HR_{max}. The independent t-test showed a difference between blood lactate levels post-SSG and blood lactate after the incremental ramp-like exercise [p = .001; F = 97.294]. Four-a-side SSG have sufficient physiological demands for female players, characterized by achieving the minimum standard of physiological response with maximum aerobic capacity.
Keywords: Sport medicine, Four-a-side, Football training, Match analysis, Metabolic demands, Performance.

Cite this article as:
Apriantono, T., Bahrul U'Lum, W., Sria Ramania, N., & Winata, B. (2025). Physiological response in professional female soccer players: Comparison between small-sided games and laboratory exercise testing. *Journal of Human Sport and Exercise, 20*(1), 290-301. https://doi.org/10.55860/4jgsky33

Corresponding author. *Department of Sports Science, School of Pharmacy, Institut Teknologi Bandung. Ganesa 10, 40132 Bandung. Indonesia.*
E-mail: tommy@fa.itb.ac.id
Submitted for publication August 28, 2024.
Accepted for publication October 23, 2024.
Published December 08, 2024.
Journal of Human Sport and Exercise. ISSN 1988-5202.

doi: https://doi.org/10.55860/4jgsky33

INTRODUCTION

Football is a sport that has the characteristics of multidirectional and intermittent field sports (Low et al., 2020; Sarmento et al., 2018). Because of these characteristics, it is not surprising that, in soccer, a good combination of physiological, technical, and tactical skills is needed to support the performance of each athlete (Vella et al., 2022). The complexity of these needs seems to be followed by increased scientific interest in this sport to help coaches improve athletic performance (Formenti et al., 2021). Unfortunately, it is necessary to recognize that the study focus is on males, and study on females is limited (Vella et al., 2022). This is unfortunate, given the strong growth in female soccer, with evidence of 1.2 million federative licenses already granted in Europe alone (Crossley et al., 2020).

To improve the performances of athletes during matches, several experts revealed that fitness factors such as maximum oxygen uptake (VO_{2max}), muscular tone, or maximum heart rate (HR_{max}) are some of the factors that can affect the performance of some high-intensity actions such as jumps, kicks, and sprints(Crossley et al., 2020; Hecksteden et al., 2022; López-Fernández et al., 2017; Sarmento et al., 2018). Interestingly, these demands can lead to acute fatigue in athletes, therefore, they are required to have high metabolic demands (Thorpe et al., 2017). In response to these challenges, coaches and sports scientists are currently conducting various types of measurements of specific drill training that aim to improve the performance of athletes according to the physiological demands during real matches (Hill-Haas et al., 2011).

Small-sided games (SSG) are one of the specific training programs that are currently popular and developing in soccer training (Clemente et al., 2021; Esposito, 2024; Hill-Haas et al., 2011). Coaches and sports scientists believe that SSG can improve the performance of athletes, considering that SSG can reproduce the technical, tactical, and even physical demands of soccer matches (Clemente et al., 2021; Hill-Haas et al., 2011). Based on this evidence, experts are currently conducting an analysis of the effectiveness of SSG in the physiological characteristics of athletes by modifying the number of players, pitch size, surface analysis, and rules (ex. the use of goals and/or goalkeepers) (Clemente et al., 2021; Hill-Haas et al., 2011). The purpose of these modifications remains the same, that is, to find an SSG design that is identical to the physiological demands during soccer matches (Clemente et al., 2021; Hill-Haas et al., 2011).

Several previous studies have proven that SSG can provide sufficient physiological characteristics to replicate the physical demands of soccer matches (Clemente et al., 2021; Hill-Haas et al., 2011; Mara et al., 2016). For example, Mara et al. (Mara et al., 2016) revealed that during SSG in males with the concept of 4 vs. 4, the players showed an average heart rate (HR_{ave}) of 87.2% of the HR_{max}. Moreover, several previous studies have also revealed that similar results: SSG of 5 vs. 5 (HR_{ave} is 89% of HR_{max}); 6 vs. 6 (HR_{ave} is 87% of HR_{max}); and 8 vs. 8 (HR_{ave} is 79% of HR_{max}) (Hill-Haas et al., 2011; López-Fernández et al., 2018). Although previous studies have reached the same conclusions, the findings remain unclear and debatable to experts (Hill-Haas et al., 2011). Various assumptions, such as the length of the game, rest period, presence or absence of keepers or goalposts, and activity profile, are some of the factors that are assumed to be the differentiators in each of these findings (López-Fernández et al., 2018).

On the other hand, from a physiological perspective, Hoff et al. (Hoff et al., 2002) stated that the relation between heart rate and oxygen uptake (VO_2) is an important factor to assess the validity of exercise intensities in soccer specific training. Specifically, this statement was proved by Hoff et al. (Hoff et al., 2002) by conducting tests between physiological response on SSG and laboratory maximum testing and concluded that HR_{ave} during SSG is 91.3% of the HR_{max}, and the VO_2 during SSG is 84.5% of the VO_{2max}. Furthermore, previous studies have also revealed that the physiological characteristics of the players are related to the activity profile based on mechanical efficiency (Alt et al., 2020; Hoppe et al., 2020). In other words, physiological training can increase or decrease the mechanical power output at a given physiological response(Hoppe et al., 2020). Therefore, it is important to understand the relationship between physiological characteristics and activity profiles (Hoppe et al., 2020).

Unfortunately, some of these studies were only conducted on male soccer players, and specific physiological changes during SSG in female soccer players have not yet been found (Hill-Haas et al., 2011; Manson et al., 2014). To the best of our knowledge, study on female soccer players is currently limited to differences in surface, metabolic, and time-motion analyses (López-Fernández et al., 2017; Manson et al., 2014). To address the gap in the literature on the physiological responses of female soccer players during SSG, the purpose of this study was to (i) describe the physiological characteristics as well as energetic requirements of SSG in female players by means of ambulatory gas exchange measurements using a breath-by-breath (B × B) approach and (ii) to assess activity profile during SSG. Therefore, we expect that these findings can add to the scientific literature on the physiological characteristics of female players and provide relevant information to coaches and athletes for designing trainings based on the use of SSGs.

MATERIALS AND METHODS

Participants

Eight professional female soccer players participated in the observational study and experimental procedures. Three of the participants were Indonesian national team athletes, and the other five were professional athletes who played in the highest caste league of Indonesian female soccer. All participants were confirmed to be in accordance with the inclusion criteria in this study, namely: (1) registered as Indonesian professional female players, (2) had a history of training 15 hours per week, (3) had participated in the minimum national competition, (4) did not smoke, or had no history of smoking; (5) had no concomitant diseases and no use of any anti-inflammatory or antioxidant drugs, (6) and had no musculoskeletal injuries in the 6 months before the start of the study. Athletes who were not familiar with the concept of SSG and did not pass the medical examination before the start of the study were excluded. The goals, benefits, and risks for all coaches and athletes were confirmed. After the participants received this information, they provided informed consent to participate. The study was approved by the local Clinical Study Ethical Committee of POLTEKKES Bandung (10/KEPK/EC/III/2023) in accordance with the Declaration of Helsinki.

Experimental design

The study was conducted for three weeks, during the break session of the Indonesian female tournament, where two measurement sessions were performed each week. All participants were asked to refrain from strenuous exercise 24 hours previous the measurement sessions, avoid drinking alcohol, and prepare themselves as they would for an official competition. All participants were asked to familiarize themselves with the procedures each session. The study was divided into two sessions: laboratory exercise and field testing. A three-day break was provided between the two sessions in order to ensure that each participant could recover. During recovery, healthy diets and light physical activity were provided to participants to maintain their fitness. In the laboratory sessions, anthropometry and an exhaustive incremental ramp-like exercise test were used to measure maximal ergometric parameters. In the field test session, participants were evaluated on a natural grace surface in the four-a-side SSG. Both tests were performed with simultaneous gas exchange measurements and were carried out at the player's regular training time (16:00 to 18:00) and weather conditions (dry; 28-30ºC; 55-60% relative humidity). The rating of perceived exertion (RPE) Borg's CR10-scale modified by Impellizzeri et al., (Impellizzeri FM, 2004) was used in both measurement sessions. where 0 indicates rest, 1 indicates very easy, 2 indicates easy, 3 indicates moderate, 4 indicates somewhat hard, 5 indicates hard; 6–7 indicate very hard; 8–10 indicate maximal.

Laboratory test

In the laboratory test session, anthropometric measurements were carried out indoors and supervised by a female medical representative (n = 1) and an administrator officer (n = 1). The body weight and body fat of each participant were measured using the Omron Digital Weight Scale HN 289, while height was measured using a Seca 214 Portable Stadiometer (Cardinal Health, Ohio, USA). During the measurement, the participants wore light clothes and were barefoot. Body mass index (BMI) was calculated as body mass (kg) divided by height (m) squared.

Following the anthropometric measurements assessment, a Lactate Pro analyser (Arkray, Shiga, Japan) was used to measure and analyse the blood lactate levels of each participant. Blood lactate was obtained from the fingertips (100 µL of sample). A standardized warm-up of 20 minutes was conducted prior to the incremental ramp exercise test. The incremental ramp exercise test was performed on a treadmill (LODE-Treadmill V2 CPET-01, Netherlands) to measure the maximal oxygen uptake and maximum heart rate (HR_{max}) of each player. During the test, HR and respiratory gas exchange were measured using short-range telemetry (Garmin HRM-Dual™, USA) and portable metabolic carts breath-by-breath basis (B×B) (Cosmed K5, Italy), respectively. The collected data were averaged over 10 seconds.

Before use, the Cosmed K5 was warmed for 60 min. Furthermore, gases calibration was carried out based on the instructions and recommendations of the Cosmed K5 guidelines (turbine gainIN = 1016; turbine gainEX = 1001; syringe = 3000mL; Vt threshold = 50 mL; flowmeter temp = 34°C), BxB cal. Factors (O_2 trimmer = 598; O_2 gain = 1029; O_2 base line = 124 mV; O_2 delay = 720 ms; O_2 speed = 1098; O_2 rise time = 190 ms; O_2 fall time = 190 ms; CO_2 trimmer = 589; CO_2 gain = 972; CO_2 base line = 3761 mV; CO_2 delay = 690 ms; CO_2 speed = 6000; CO_2 rise time = 90 ms; CO_2 fall time = 90 ms; PCal B × B = 727 mmHg), and gas reference (cylinder O_2 = 16%, cylinder CO_2 = 5%, ambient O_2 = 20.93%, ambient CO_2 = 0.04%).

The protocol of the incremental ramp-like exercise test was adopted from previous studies (Apriantono et al., 2020; Winkert et al., 2020). Before the start of the measurement session, participants were asked to use the Cosmed K5 mask based on the size of each participant. In this session, each participant ran for 4 min at 10 km/h at an inclination of 1% and 5%, respectively. The treadmill speed was increased by 2 min at 1 km/h until exhaustion was reached. Exhaustion was defined as the plateau attained by the relationship between oxygen uptake (VO_2) and running speed. Maximal oxygen uptake and HR were defined as the highest recorded values during incremental ramp-like exercises. Immediately after the test, blood lactate levels were obtained. In this session, laboratory officers (n = 2) and administrators (n = 1) assisted with installation details and control over data retrieval.

Small side games (SSG) field test

In this study, we considered and used the four-a-side SSG recommended by Mara et al. (Mara et al., 2016), considering that this SSG formula is widely used in study and is familiar to female soccer players in several previous studies. On the other hand, the findings of Zubillaga et al. (Zubillaga et al., 2013) also strengthen this study as this study encouraged the achievement of individual player areas in matches ranges from 77.91 ± 32.72 m^2 to 96.19 ± 22.66 m^2, as well as ratio ranges from 1:1 to 1:1.3. The details of the SSG provisions are listed in Table 1.

Prior to the start of the SSG, the study had coaches actively involved in encouraging players to make the maximum effort. On the other hand, the SSG asks the players to all possessions for as much time as possible. Eight participants were divided, consisting of a full back (n = 2), a playmaker (n = 4), and a striker (n = 2), divided into two separate teams (one team consisted of a fullback, two playmakers, and one striker). There were no goalposts or keepers involved in this study, considering that the intensity of the game is improved in this situation (Mara et al., 2016).

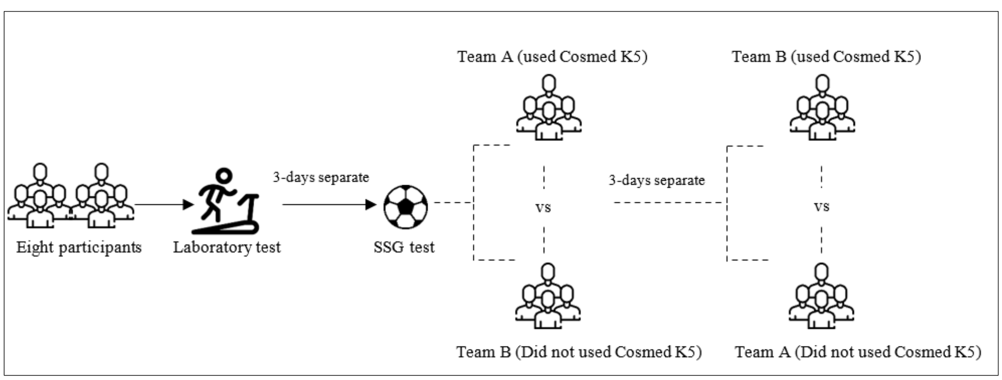
One of the teams competed using the Cosmed K5 against the team that did not use the Cosmed K5. Two matches were used for the field test analysis (Figure 1). One for the match design). A total of 3 min of recovery that allowed 2 min of passive recovery (participants were allowed to drink water *ad libitum* to prevent dehydration), and then 1 min of active recovery work (low-intensity ball-passing exercises) prior to the second half of the session were provided to the players. During passive recovery, internal load measurements were not performed using the Cosmed K5. A three-day break was given between the two matches of the SSG field test to provide a total recovery.

During the SSG, each participant wore a portable metabolic device, which was placed on the back of the player, and a mask according to the face size of each player (Cosmed K5, Italy). Specifically, the Cosmed K5 output measurements during the match simulation were VO_2, HR_{ave}, breath frequency (fB), minute ventilation (VE), energy expenditure (EE), and VO_2/HR. The weight of the Cosmed K5 was 900 g (see Figure. 2). The Garmin HRM-Dual™ (USA) was used to measure the HR during the match. During this field test session, lactic acid measurements were performed before the start of the match and immediately after the match. Lactic acid measurements were performed using a lactate pro analyser (Arkray, Shiga, Japan), and were obtained from the fingertips (100 µL sample). The collected data were averaged over 10 s and analysed in relation to the maximal values achieved during the laboratory treadmill tests.

Table 1. Detail of four-a-side SSG characteristics.

Game duration (min)	Duration of the recovery between SSG matches	Pitch area (m)	Pitch total area (m^2)	Pitch ratio per player (m^2)
4	2 min (passive); 1 min (active)	20 x 20	400	50

Notes: SSG – small side games.



Notes: SSG – small side games; Three-day breaks between each session were used for recovery.

Figure 1. Flow of data measurements on laboratory and SSG field testing.

Activity profiles

In this study, professional technical coaches (n = 2), who had experience in technical training of female soccer players for a minimum of 10 years, were involved in the analysis of activity profiles. Two match analyses were performed by technical coaches. The assessment of activity profiles during SSG was based on a previous method (López-Fernández et al., 2017; Mara et al., 2016; Zubillaga et al., 2013), and included: (i) The total passes are the total number of times the player kicks the ball (success or failed) to another member of their team during SSG; (ii) A successful pass occurs when the player kicks the ball and the ball is received by another member of their team; (iii) A failed pass occurs when the player kicks the ball and the ball is not received by another member of their team.

Statistical analysis

Statistical analysis was performed using IBM SPSS software version 25.0. All data were tested for normal distribution using the Shapiro-Wilk test and Levene's statistics. The one-way analysis of variance (ANOVA) with an independent t-test was used to determine differences in blood lactate and RPE variables. Confidence intervals (95% CI) were calculated to indicate the magnitude of the change. Statistical significance was set at $p < .05$.

RESULTS

Anthropometry and activity profile

Table 2 describes the anthropometric characteristics of professional female soccer players, who have an average age of 20.5 ± 1.51 years. In the activity profile analysis, in two matches, the average number of passes was 76 ± 5.65 passes, with a total of 152 passes in the two matches. Specifically, 85.53% of the total passes were categorized as successful passes, and 14.47% were categorized as failed passes (see Table 3).

Table 2. Anthropometric characteristics of Indonesian female soccer players.

Variables	$\bar{X}(SD)$
Weight (kg)	50.14 ± (4.85)
Height (cm)	156.6 ± (3.35)
BMI (kg/m^2)	20.41 ± (1.67)
Body fat (%)	23.40 ± (2.51)

Table 3. Activity profile during SSG.

Total pass ($\bar{X} \pm SD$)	Successful pass ($\bar{X} \pm SD$)	Failed pass ($\bar{X} \pm SD$)
76 ± 5.65	65 ± 1.41	11 ± 2.82

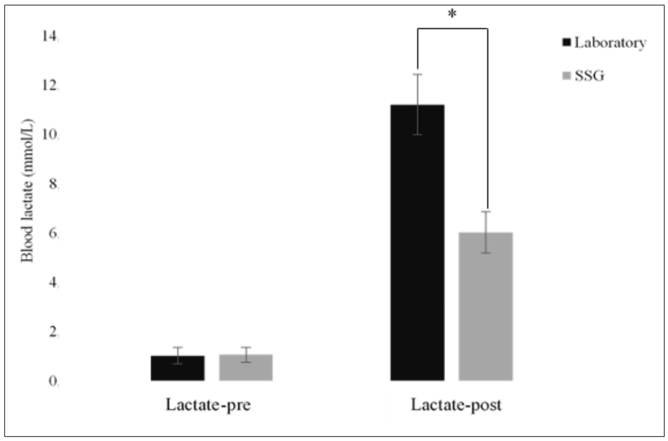
Table 4. Physiological characteristics of female soccer players during laboratory and SSG field tests

Variable	($\bar{X} \pm SD$)
VO_{2max} (mL/min/kg)	49.32 ± 1.68
VO_2 (mL/min/kg)	41.38 ± 5.11
HR_{max} (Bpm)	193.39 ± 7.42
HR_{ave} (Bpm)	163.25 ± 8.75
f_B (min^{-1})	52.62 ± 3.86
V_E (l min^{-1})	60.31 ± 4.98
EE (kcal/min)	9.81 ± 1.29
VO_2/HR (mL/beat)	13.66 ± 1.35

Abbreviations: VO_{2max}, average maximum oxygen uptake during the incremental ramp exercise test; VO_2 – average oxygen uptake during match simulation; HR_{max} – average maximum heart rate during the incremental ramp exercise test; HR_{ave} – average heart rate during match simulation; f_B – breathing frequency during match simulation; V_E – minute ventilation; EE – energy expenditure; VO_2/HR – heart Rate and O_2 Pulse.

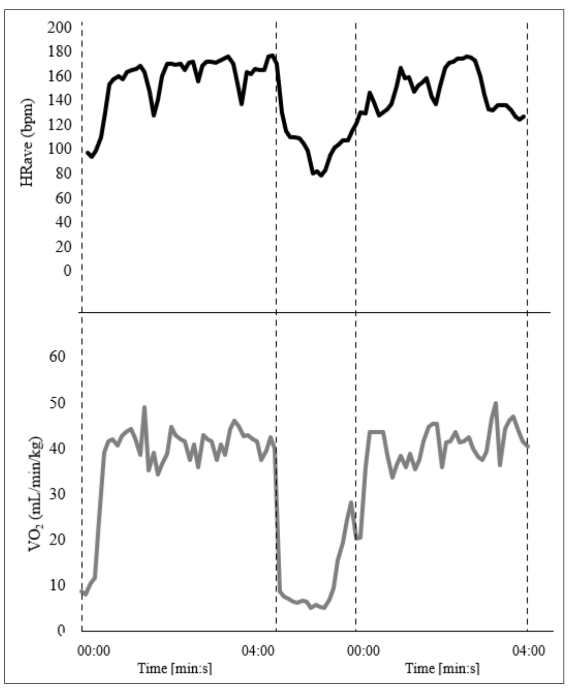
Physiological characteristics

The ANOVA test showed that there was no significant difference in lactate levels pre-SSG with the lactate levels incremental during the incremental ramp-like exercise Y [*p* = .818; F = 0.055], however, there was a significant difference between blood lactate levels post-SSG and after the incremental ramp-like exercise [*p* = .001; F = 97,294] (Figure 2). Regarding physiological measurements, during laboratory and field tests, the results showed that VO_2 during SSG was 83.90% of the VO_{2max}, and the HR_{ave} during SSG was 84.42% of the HR_{max} (see Table 4 and Figure 3 to see a detailed comparison of physiological characteristics during SSG). On the other hand, there were significant differences between laboratory and SSG field tests results on the RPE Borg's CR10-scale [*p* = .001; F = 18,667] (Figure 4).



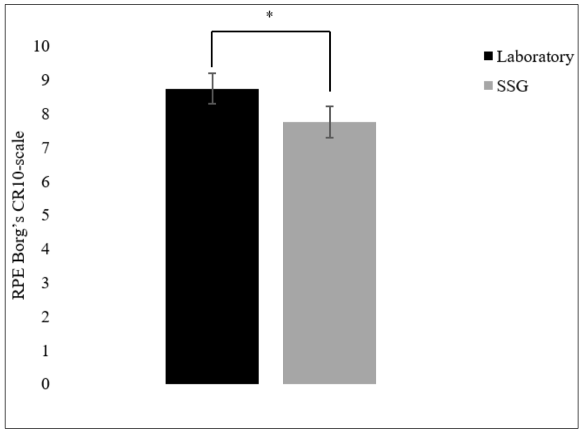
*Notes. Lactate-pre – blood lactate response before laboratory and SSG field test, Lactate-post – blood lactate response after laboratory and SSG field test. *Statistically significant differences between lactate levels during laboratory and SSG tests (p < .05).*

Figure 2. Changes in female soccer players during laboratory and SSG field tests.



Notes. VO_2 – average oxygen uptake during SSG; HR – average heart rate during SSG. Rest time between rally is three minutes.

Figure 3. VO_2 and HR results during SSG of female soccer players.



*Notes. RPE - Rating of perceived exertion Responds. *Statistically significant differences between lactate levels during laboratory and SSG tests (p < .05).*

Figure 4. Differences of RPE Borg's CR10-scale between laboratory and SSG field tests.

DISCUSSION

The aim of this study was to describe the physiological characteristics and energetic requirements of SSG in female players by means of ambulatory gas exchange measurements using a breath-by-breath (B × B) approach, and to assess the activity profile during SSG. In line with the study objectives, this study succeeded in revealing quantitative facts related to the physiological characteristics of female soccer players. The major findings are as follows: (1) this study shows that SSG reflects a training regimen design that can build the aerobic capacity of female soccer players by showing a physiological response that is close to the high aerobic capacity of female soccer players; (2) physiological responses during SSG reflect that it is intermittent training, evidenced by a significant difference in post-intervention lactate levels between the laboratory test and the SSG field test; and (3) SSG can improve technical and tactical skills, as evidenced by more successful passes than failed passes.

This study used four-a-side SSG as a design in the data collection process. Although many experts modify SSG based on the number of players, pitch size, analysis surfaces, and rule modifications, four-a-side SSG are considered to be one of the most desirable exercise designs because they can satisfy the physiological demands of female players (López et al., 2019; López-Fernández et al., 2017, 2018; Mara et al., 2016). This is in line with the findings of this study, which support previous study (Mara et al., 2016). This study revealed that HR_{ave} during SSG was 84.42% of the HR_{max}, which is in line with study conducted by Mara et al., (Mara et al., 2016) where the results stated that four-a-side SSG can be used as an exercise design that can perform aerobic conditioning stimulus and increase the anaerobic ability of female players, when compared to medium-side games (MSG) and large-sided games (LSG). This is indicated by the higher percentage of HR_{ave} of the HR_{max} responses during SSG (87.2 ± 5.7%) compared to MSG (86.3 ± 6.1%) and LSG (83.9 ± 4.9%).

Most of the previous studies revealed that the HR_{ave} during SSG of various sizes showed similar results, with an average of >80% of the HR_{max}. Only the study conducted by Della et al., (Dellal et al., 2012) where 8 vs. 8 male players performed SSG at a pitch dimension of 60 × 45, with a time of 4 × 4 min/3 min rest, resulted in an HR_{ave} of 71.7 ± 6.3% of the HR_{max}. Meanwhile, there has been no study on female soccer players that shows an HR_{ave} <80% of the HR_{max} during SSG of various sizes. In response to this phenomenon, this study agrees with Hill-Haas et al., (Hill-Haas et al., 2011) who stated in their systematic review that motivational, technical and tactical factors, the number of players, and even the surface when performing SSG can affect the intensity of the game, resulting in HR_{ave} variations among various types of methods of SSG.

To the best of our knowledge, there is no study that is quantitatively related to VO_2 during SSG in female soccer players. Until now, study related to VO_2 during SSG has only been conducted in male players. For example, Hoff et al. (Hoff et al., 2002) analysed the internal loads on six male soccer players using five-a-side football SSG and found that the HR_{ave} during these was 91.3% of the HR_{max}, and the VO_2 was 84.5% of the VO_{2max}. Therefore, this study cannot compare the results of this study in a balanced way with previous studies, but it can be understood that the physiological responses during SSG in female and male soccer players seem to have similarities. The reason is, our results shown the VO_2 percentage response was very similar to the results of Hoff et al. (83.90% and 84.5% of VO_{2max}) (Hoff et al., 2002).

The physiological responses found in this study can strengthen previous evidence, which supports the idea that SSG is a training method that provides sufficient physiological demands for soccer players, especially female players. For example, Ohlsson et al. (Ohlsson et al., 2015) stated that HR_{ave} should reach 81–87% of their individual HR_{max} to reproduce the physiological demands of real matches. Considering that the quantitative results in this study show an HR_{ave} during four-a-side SSG of 84.42% of the HR_{max}, it provides evidence for female soccer players and athlete trainers to use SSG as an exercise design that can replicate the physical demands of soccer matches. Furthermore, the results of this study can complement previous studies on female soccer players, which were limited to several variables such as interface surface, metabolic power, time motion analysis and speed, and difference in pitch size during SSG.

In addition to important findings related to HR_{ave} and VO_2 responses during SSG, the findings in this study also reveal another interesting phenomenon, where post-intervention lactate levels during laboratory tests was significantly higher than post-intervention lactate levels during the SSG field test. This seems to emphasize that the SSG is a training design that reflects the characteristics of soccer matches, namely intermittent field sports. This can be observed from the low lactate levels after the SSG field test. The systematic review revealed by Proia et al. (Proia et al., 2016) seems to provide some explanation to this phenomenon. As a result of performing SSG intermittently, Cori's cycle can occur, in which lactate derived from the muscles is transported to the liver through gluconeogenesis to synthesize glucose, which then enters the bloodstream. Furthermore, Cori's cycle does not cause high lactate results after the SSG field test in this study.

Although this study has provided a novel approach regarding the physiological characteristics of female soccer players, there are some limitations. First, this study did not consider the influence of the circadian rhythm and menstruation rhythm on the physiological measurements in female soccer players. Second, this study only measured physiological responses in four-a-side SSG, hence, future studies should examine the different physiological responses in female soccer by comparing the interface surface, pitch size, and number of players during SSG. Third, regarding blood samples, we only analysed lactate levels, therefore, we encourage future studies to use blood biomarkers such as creatine kinase (CK), C-reactive protein (CRP), serum glutamic oxaloacetic transaminase (SGOT), or serum glutamic pyruvic transaminase (SGPT) to address the unanswered questions in this study.

CONCLUSION

This study shows that four-a-side SSG meet the physiological demands of female soccer players, marked by the achievement of a minimum standard of physiological response with maximum aerobic capacity.

Therefore, the use of four-a-side SSG can be recommended for coaches and female soccer players to increase aerobic capacity while still paying attention to the concept of developing an activity profile.

Practical implication

This study has concretely explained the physiological characteristics during SSG and the match activity profile, especially in professional female soccer players. Based on the findings of this study, we can provide the following recommendations to female soccer athletes and coaches to consider : (1) Four-a-side SSG quantitatively (VO_2 during SSG is 83.90% of VO_{2max}, and HR_{ave} during SSG is 84.42% of HR_{max}) can be assessed as a training regimen design that illustrates the importance of aerobic needs in soccer in female players, therefore, they can be considered as an appropriate exercise that can improve aerobic performance; (2) coaches and athletes should be encouraged to pay more attention to tactics in the use of four-a-side SSG, considering that these tactics can affect the development of the athlete's activity profile; and (3) paying attention to environmental factors such as temperature, surface, as well as dehydration and rehydration factors in conducting four-a-side SSG should be promoted, considering that some of these components can affect the quality of training.

AUTHOR CONTRIBUTIONS

Conceptualization: Tommy Apriantono, Nia Sri Ramania, Wildan Bahrul U'Lum, Bagus Winata. Data curation: Wildan Bahrul U'Lum. Investigation: Bagus Winata, Wildan Bahrul U'Lum. Methodology: Tommy Apriantono, Nia Sri Ramania, Wildan Bahrul U'Lum. Supervision: Tommy Apriantono. Validation: Tommy Apriantono, Bagus Winata. Visualization: Wildan Bahrul U'Lum. Writing – original draft: Bagus Winata. Writing – review & editing: Bagus Winata, Tommy Apriantono. All co-authors have contributed to the published work and agree to its publication in JHSE.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

ACKNOWLEDGMENTS

The authors would like to thank the West Java Indonesian football association and West Java Provincial Youth and Sports who supported this study.

REFERENCES

Alt, P. S., Baumgart, C., Ueberschär, O., Freiwald, J., & Hoppe, M. W. (2020). Validity of a local positioning system during outdoor and indoor conditions for team sports. In Sensors (Switzerland) (Vol. 20, Issue 20, pp. 1-11). MDPI AG. https://doi.org/10.3390/s20205733

Apriantono, T., Herman, I., Winata, B., Hidayat, I. I., Hasan, M. F., Juniarsyah, A. D., & Ihsani, S. I. (2020). Physiological characteristics of Indonesian junior badminton players: Men's double category. International Journal of Human Movement and Sports Sciences, 8(6), 444-454. https://doi.org/10.13189/saj.2020.080617

Clemente, F. M., Afonso, J., & Sarmento, H. (2021). Small-sided games: An umbrella review of systematic reviews and meta-analyses. PLoS ONE, 16(2 Febuary). https://doi.org/10.1371/journal.pone.0247067

Crossley, K. M., Patterson, B. E., Culvenor, A. G., Bruder, A. M., Mosler, A. B., & Mentiplay, B. F. (2020). Making football safer for women: A systematic review and meta-Analysis of injury prevention programmes in 11 773 female football (soccer) players. In British Journal of Sports Medicine (Vol. 54, Issue 18, pp. 1089-1098). BMJ Publishing Group. https://doi.org/10.1136/bjsports-2019-101587

Dellal, A., Owen, A., Wong, D. P., Krustrup, P., van Exsel, M., & Mallo, J. (2012). Technical and physical demands of small vs. large sided games in relation to playing position in elite soccer. Human Movement Science, 31(4), 957-969. https://doi.org/10.1016/j.humov.2011.08.013

Esposito, G. (2024). The impact of visual occlusion during small-sided games on youth football players. Journal of Human Sport and Exercise, 19(3), 882-890. https://doi.org/10.55860/br654n60

Formenti, D., Rossi, A., Bongiovanni, T., Campa, F., Cavaggioni, L., Alberti, G., Longo, S., & Trecroci, A. (2021). Effects of non-sport-specific versus sport-specific training on physical performance and perceptual response in young football players. International Journal of Environmental Research and Public Health, 18(4), 1-11. https://doi.org/10.3390/ijerph18041962

Hecksteden, A., Kellner, R., & Donath, L. (2022). Dealing with small samples in football research. Science and Medicine in Football, 6(3), 389-397. https://doi.org/10.1080/24733938.2021.1978106

Hill-Haas, S. V, Dawson, B., Impellizzeri, F. M., & Coutts, A. J. (2011). Physiology of Small-Sided Games Training in Football A Systematic Review. Sports Med, 41(3), 199-220. https://doi.org/10.2165/11539740-000000000-00000

Hoff, J., Wisløff, U., Engen, L. C., & Kemi, O. J. (2002). Soccer specific aerobic endurance training. Br J Sports Med, 36, 218-221. https://doi.org/10.1136/bjsm.36.3.218

Hoppe, M. W., Hotfiel, T., Stückradt, A., Grim, C., Ueberschär, O., Freiwald, J., & Baumgart, C. (2020). Effects of passive, active, and mixed playing strategies on external and internal loads in female tennis players. PLoS ONE, 15(9), e0239463. https://doi.org/10.1371/journal.pone.0239463

Impellizzeri FM, R. E. C. A. S. A. M. S. (2004). Use of RPE-Based Training Load in Soccer. Med Sci Sports Exerc ., 36(6), 1042-1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Lopez, J., Lopez-Fernandez, L., Fernandez, F., Gallardo, L., Lvaro, A., Fernandez-Luna, F., Villacañas, V., Villacañas, V., Garcia, J., Garcia-Unanue, G., Sanchez, J., Sanchez-Sanchez, S., & Sanchez, S. (2019). Pitch Size and Game Surface in Different Small-Sided Games. Global Indicators, Activity Profile, and Acceleration of Female Soccer Players. J Strength Cond Res, 33(3), 831-838.

López-Fernández, J., Sánchez-Sánchez, J., Gallardo, L., & García-Unanue, J. (2017). Metabolic power of female footballers in various small-sided games with different pitch surfaces and sizes. Sports, 5(2). https://doi.org/10.3390/sports5020024

López-Fernández, J., Sánchez-Sánchez, J., Rodríguez-Cañamero, S., Ubago-Guisado, E., Colino, E., & Gallardo, L. (2018). Physiological responses, fatigue and perception of female soccer players in small-sided games with different pitch size and sport surfaces. Biology of Sport, 35(3), 291-299. https://doi.org/10.5114/biolsport.2018.77829

Low, B., Coutinho, D., Gonçalves, B., Rein, R., Memmert, D., & Sampaio, J. (2020). A systematic review of collective tactical behaviours in football using positional data. Sports Med, 50(2), 343-385. https://doi.org/10.1007/s40279-019-01194-7

Manson, S. A., Brughelli, M., & Harris, N. K. (2014). Physiological characteristics of international female soccer players. J Strength Cond Res, 28(2), 308-318. https://doi.org/10.1519/JSC.0b013e31829b56b1

Mara, J. K., Thompson, K. G., & Pumpa, K. L. (2016). Physical and physiological characteristics of various-sided games in elite women's soccer. International Journal of Sports Physiology and Performance, 11(7), 953-958. https://doi.org/10.1123/IJSPP.2015-0087
Ohlsson, A., Berg, L., Ljungberg, H., Söderman, K., & Stålnacke, B. M. (2015). Heart Rate Distribution during Training and a Domestic League Game in Swedish Elite Female Soccer Players. Ann Sports Med Res, 2(4), 1025.
Proia, P., di Liegro, C. M., Schiera, G., Fricano, A., & Di Liegro, I. (2016). Lactate as a metabolite and a regulator in the central nervous system. In International Journal of Molecular Sciences (Vol. 17, Issue 9). MDPI AG. https://doi.org/10.3390/ijms17091450
Sarmento, H., Anguera, M. T., Pereira, A., & Araújo, D. (2018). Talent Identification and Development in Male Football: A Systematic Review. Sports Medicine, 48(4), 907-931. https://doi.org/10.1007/s40279-017-0851-7
Thorpe, R. T., Atkinson, G., Drust, B., & Gregson, W. (2017). Monitoring fatigue status in elite team-sport athletes: Implications for practice. In International Journal of Sports Physiology and Performance (Vol. 12, pp. 27-34). Human Kinetics Publishers Inc. https://doi.org/10.1123/ijspp.2016-0434
Vella, A., Clarke, A. C., Kempton, T., Ryan, S., & Coutts, A. J. (2022). Assessment of Physical, Technical, and Tactical Analysis in the Australian Football League: A Systematic Review. In Sports Medicine - Open (Vol. 8, Issue 1). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1186/s40798-022-00518-8
Winkert, K., Kirsten, J., Dreyhaupt, J., Steinacker, J. M., & Treff, G. (2020). The COSMEd K5 in breath-by-breath and mixing chamber mode at low to high intensities. Medicine and Science in Sports and Exercise, 52(5), 1153-1162. https://doi.org/10.1249/MSS.0000000000002241
Zubillaga, A., Gabbett, T. J., Fradua, L., Ruiz-Ruiz, C., Caro, Ó., Ervilla, R., Macrae, H., & Wheeler, K. (2013). Influence of Ball Position on Playing Space in Spanish Elite Women's Football Match-Play. International Journal of Sports Science & Coaching, 8(4). https://doi.org/10.1260/1747-9541.8.4.713